PB81-213241

Wastewater Treatment by Rooted Aquatic Plants in Sand and Gravel Trenches

Moulton Niguel Water District
Laguna Niguel, CA

Prepared for

Municipal Environmental Research Lab
Cincinnati, OH

Jun 81

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/2-81-091	ORD Report	PB81 213241

4. TITLE AND SUBTITLE	5. REPORT DATE
Wastewater Treatment by Rooted Aquatic Plants in Sand and Gravel Trenches	June 1981 (Issuing Date)
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Pamela R. Pope	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Moulton Niguel Water District Laguna Niguel, California 92677	AZB1B - D.U. B-113
	11. CONTRACT/GRANT NO.
	Grant No. R-805279
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Municipal Environmental Research Laboratory--Cin.,OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268	Final 8/77-8/79
	14. SPONSORING AGENCY CODE
	EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: Dr. R. Lewis (513) 684-7641

16. ABSTRACT

The Moulton Niguel Water District of Laguna, California constructed and operated an earthen trench system employing rooted aquatic plants for the treatment of wastewater. Two trenches in series were planted with the reed Phragmites and the bulrush Scirpus, respectively.

A two-month study using conventional secondary effluent as the trench influent showed the system was not effective for removal of nitrogen and phosphorus components.

An eleven-month study demonstrated that raw screened wastewater applied to the trench system at a rate not exceeding 95 m^3/d (25,000 gpd) could be treated to secondary effluent quality. Spatial requirements were about the same as for a septic tank system.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Wastewater Biological Removal* Harvesting* Flora	Rooted Aquatic* Waste Treatment* Earthen Trenches Reeds Bulrush	13B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to Public	Release to Public	31
	20. SECURITY CLASS *(This page)*	22. PRICE
	Release to Public	

EPA Form 2220-1 (9-73)

EPA-600/2-81- 091
June 1981

PB81-213241

WASTEWATER TREATMENT BY ROOTED AQUATIC PLANTS IN SAND AND GRAVEL TRENCHES

by

Pamela R. Pope
Moulton Niguel Water District
Laguna Niguel, California 92677

Grant No. R-805279

Project Officer

Ronald F. Lewis
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROCTECTION AGENCY
CINCINNATI, OHIO 45268

PRODUCT OF:
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. The complexity of the environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and Development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

As part of these activities, this report was prepared to make available to the sanitary engineering community the results of field tests of a process developed in West Germany that utilizes reeds and bulrushes planted in trenches for treatment of wastewater.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

ABSTRACT

The Moulton Niguel Water District of Laguna, California, constructed and operated an earthen trench system employing rooted aquatic plants for the treatment of wastewater. Two trenches in series were planted with the reed Phragmites and the bulrush Scirpus, respectively.

A two-month study using conventional secondary effluent as the trench influent showed the system was not effective for removal of nitrogen and phosphorus components.

An 11-month study demonstrated that raw screened wastewater applied to the trench system at a rate not exceeding 95 m^3/d (25,000 gpd) could be treated to secondary effluent quality. Spatial requirements were about the same as for a septic tank system.

CONTENTS

Page

Foreword iii

Abstract iv

Figures vi

Tables vi

1. Introduction 1

2. Conclusions 3

3. Recommendations 4

4. Description of MPI System 5

5. Operational Experiences 11

6. Results and Discussion 16

FIGURES

Number		Page
1.	MPI System at Mouton Niguel, CA	6
2.	Elevation View of Filter Trench	7
3.	Elevation View of Elimination Trench	9

TABLES

Number		Page
1.	Tertiary Treatment Results for MPI System	17
2.	Secondary Treatment Results for MPI System	19

SECTION 1

INTRODUCTION

The objective of this project was to evaluate a patented process developed by the Max Planck Institute (MPI) of West Germany for the treatment of industrial wastes, as an energy-efficient method for the treatment of municipal wastewater. The major goal was to achieve effluents meeting the United States Federal Effluent Standards by this novel biological treatment process that uses a minimal amount of mechanical equipment and does not require a great amount of manpower for normal operation.

HISTORY

Dr. Kaethe Seidel, who led a working group at the Institute of Plant Genetics of the Max Planck Association, is primarily responsible for the development of this novel biological treatment method. Biological Water Purification of California, Inc. (BWP) headed by Mr. James E. O'Connor was the California sub-licensee for the MPI system; BWP of New York, headed by Mr. L. Banks, is the general licensee of the patent (U.S. Patent 3,770,623; November 6, 1973) and has an installation in Long Island, New York.

In May 1976, a joint pilot project was put into operation by BWP of California and the Moulton Niguel Water District (MNWD), a public agency formed in 1961 under the Special District's Act. MNWD is engaged in providing domestic and irrigation water, wastewater collection treatment, and disposal within its geographical service area. The pilot project was located at the 3A facility of the MNWD plant in Mission Viejo, California. A daily loading of 75 m^3 (20,000 gpd) of raw wastewater was used in this study. An EPA Research Grant was applied for based on initial data collected during this study. The grant was awarded in August 1977 with MNWD as the grantee and James E. O'Connor of BWP of California as the Project Director. The project period was to be from September 15, 1977 to September 14, 1979.

The construction of new trench systems was planned to begin in mid-January and operation was expected at the beginning of March. Because of excessive rain, major construction did not start until the end of March 1978, and was completed in the beginning of June 1978.

The first two months of the project were devoted to testing the MPI system as a tertiary treatment process. This was done upon request by interested parties associated with MNWD. This phase of the study lasted from the end of June 1978 until the end of August 1978 with an average daily flow of 95 m^3d (25,000 gpd).

Starting in mid-September, raw wastewater was used as influent for the system to evaluate capability for secondary treatment. Testing was to continue for one year in order to determine the effects of seasonal changes on the development and performance of the MPI system. Flow was started at 57 m^3/d (15,000 gpd), and it was hoped that a maximum flow of 190 m^3/d (50,000 gpd) could be achieved by the end of the project.

The project was terminated short of the September date due to the death of the Project Director, James E. O'Connor.

SECTION 2

CONCLUSIONS

(1) Nutrient concentrations were not reduced to low enough levels in the effluent to consider the MPI system as a tertiary treatment system.

(2) The MPI system operated as a secondary treatment system appears to be an alternative to conventional secondary treatment systems for subdivision size facilities. The spatial requirements are about the same as a septic tank system.

(3) The effluent from the MPI system, when operated as a secondary treatment system, met the Federal Effluent Discharge Standards for BOD_5 and suspended solids when the flow did not exceed 95 m^3/d (25,000 gpd).

(4) The Phragmites and Scirpus plants grew well in all seasons and all weather conditions of southern California.

(5) The plants required harvesting approximately every four months; if left unharvested, they degenerated, collapsed and lay down on the trenches.

(6) The MPI system appears to perform most efficiently with flows of 57-95 m^3/d (15,000-25,000 gpd) through the filter trench. A flow of 133 m^3/d (35,000 gpd) lead to a poorer quality effluent and caused operational problems.

(7) Bacteriological tests indicated that disinfection of the MPI effluent would be needed to meet a total coliform standard of 1,000 per 100 ml.

SECTION 3

RECOMMENDATIONS

(1) Further studies should be conducted in other parts of the United States to determine whether the MPI system can be used in colder climates.

(2) For future pilot plant size or full-scale systems, improved engineering design of the freeboard level in the filter trenches and the method of applicaiton of the filter trench effluent to the beginning of the elimination trench may prevent some of the operational problems noted.

(3) A lower loading rate and use of more filter trenches with a longer period of drying between each cycle an individual filter bed is loaded may prevent the clogging problems experienced in this study.

SECTION 4

DESCRIPTION AND OPERATIONAL METHODOLOGY OF THE MPI SYSTEM

The MPI process utilizes higher aquatic plants, such as reeds and bulrushes, for the treatment of wastewater. The system consists of two earthen trenches, lined with impervious membranes, operated in series. The first trench, designated as the filter trench, removes coarse suspended solids from the wastewater. The second trench, designated as the elimination trench, removes dissolved materials from the effluent of the first trench.

The MNWD services a residential area and the wastewater is domestic in nature. The MPI system, as it was installed at the MNWD 3A facility, consists of two filter trenches and two elimination trenches. Two species of plants were used for the project, a reed Phragmites communis in the filter trench and a bulrush Scirpus lacustris in the elimination trench. Figure 1 is a plan view of the trench system.

The two filter trenches are each 25 m (75 ft) long and 4 m (12 ft) wide and 1.3 m (4 ft) deep. They are filled with three layers of gravel 150 mm (6 in) of 50 mm (2 in) gravel on the bottom, 225 mm (9 in) of 19 mm (3/4 in) gravel as the middle layer, and 75 mm (3 in) of pea gravel above. A 75 mm (3 in) layer of silica sand covers the top. Figure 2 is an elevation view of a filter trench. The raw wastewater enters the MNWD 3A facility at the north side of the plant and is passed through a rotostrainer for removal of large particles.

The screened influent flows down an influent channel and is pumped to the MPI system at a rate of approximately 8.8 to 9.5 x 10^{-4} m^3/s (14-15 gpm). The influent then flows south through a control valve into the east end of the filter trenches. Every 24 hours, the flow is alternated between the two trenches. Each filter trench contains a central 150 mm (6 in) plastic pipe with an open slit running its entire length with alternating long and short smaller 100 mm (4 in) plastic pipes extending from it for even dispersion of the influent. The wastewater flows down the central pipe through the extending pipes and onto cement splash pads located directly below. The wastewater percolates through the trench in a vertical filtering action leaving a sludge layer on top. The sand filters out the suspended solids while the plant system draws moisture and nutrients. Slow drying of the deposited solids occurs and extensive growth of the plant rootlets and runners aid in the degradation of the sludge layer on top of the sand. Each trench has a perforated 100 mm (4 in) plastic pipe extending the entire length of the trench from the surface to the bottom in a "U" shaped configuration. Flow from the underdrain goes into this pipe and through pipe extensions and a butterfly valve into a sump. This pipe not only transports the flow but allows aeration to the bottom

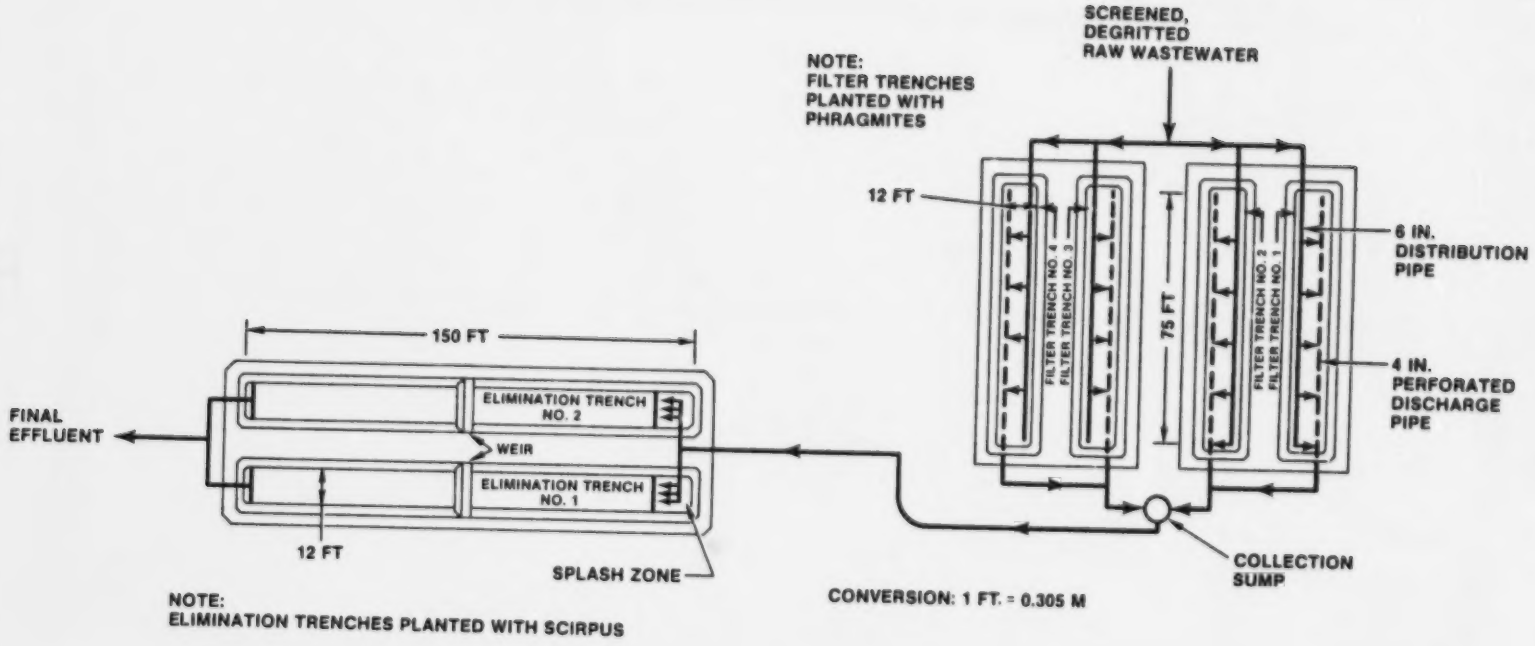

Figure 1. MPI system at Moulton Niguel, CA.

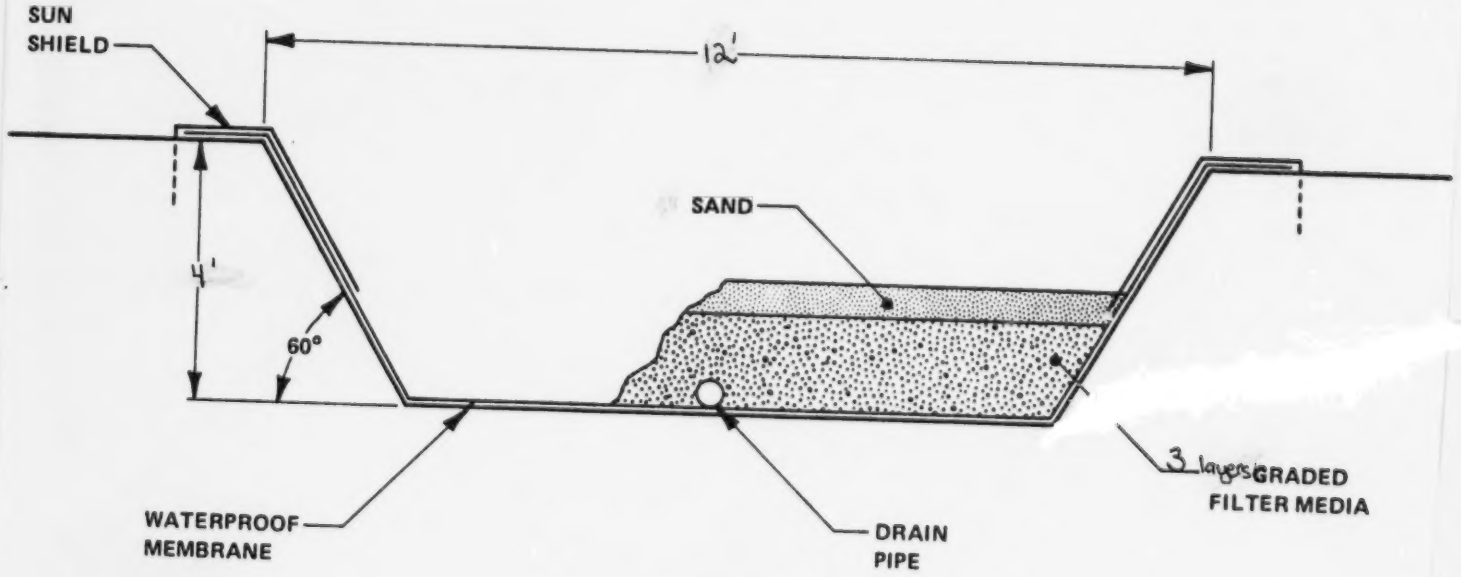

Figure 2. Elevation view of filter trench.

since it has openings to the surface. The sump is a 1.3 m (48 in) concrete pipe 3.3 m (10 ft) in height and is buried 2.6 m (8 ft). The flow is then periodically pumped by a small 0.25 kW (0.33 hp) pump, activated by a float, to the elimination trenches.

Normally, this process would be a total gravity flow system, and the elimination trenches should be placed to facilitate this, but because of site conditions at this location, the elimination trenches had to be constructed 90 m (100 yds) north of the filter trenches. The two elimination trenches are 50 m (150 ft) long, 4 m (12 ft) wide, and 0.75 m (2.5 ft) deep. They are divided in the center by a weir, which was designed to allow composite sampling in this area and to aid in aeration. Figure 3 is an elevation view of an elimination trench. The filter trench effluent enters two 150 mm (6 in) ACP pipes 4 m (12 ft) long set perpendicular to the trenches at the south side. The side facing the trenches is open, and the liquid is allowed to flow out into an area 1.3 m (4 ft) by 4.0 m (12 ft) in a waterfall-like action. This area is filled with 15 mm (5/8 in) gravel which is held in place by 50 x 100 mm (2 x 4 in) wood baffels. A subsequent observation by BWP of New York showed that elimination of the baffles gave less operational problems. The liquid percolates down in a horizontal manner at a level approximately up to 50 mm (2 in) below the surface of the trenches. The trenches are filled with 15 mm (5/8 in) gravel with 75 mm of pea gravel on top. The flow passes through the weir and runs into two standpipes that lead into a sump. The level of the liquid flow in the elimination trenches is governed by raising or lowering the standpipes. A valve in the bottom of the weir allows periodic draining of the liquid in the lower portions of the trenches. The total retention time for the entire system is estimated to be 6 hr and 8.5 hr at flows of 133 m^3/d and 95 m^3/d, respectively.

Flow meters were originally installed in the influent and final effluent lines to measure net loss due to evaporation and transpiration, and for calculation of retention time. The effluent line meter was removed in mid-August when it was found to be greatly impeding flow from the sump pump. The influent meter clogged immediately upon switching the system to raw wastewater in mid-September and had to be removed. After this, flow was determined by timing the filling of a known volume container from a pipe set up for the purpose of diverting all the flow for the measurement.

Both type trenches were lined with a Gulf Seal polyethylene liner. All effluent from this system was pumped directly back into the Trabuco sewer line since this was a demonstration study.

The filter trenches were plated with the reed Phragmites by placing root system shoots evenly spaced about 50 mm (2 in) below the surface of the entire trench. The four sections of the elimination trenches were planted alternately with two type plants, so that each trench was plated half with the Phragmites and half with the Scirpus. By this alternate planting, laboratory results might show whether or not one plant was superior for dissolved organic pollutants and nutrient removal.

Twelve composite sampling sites were established, eight of these were used for daily sampling while the other four sampling sites were available for special use, if needed.

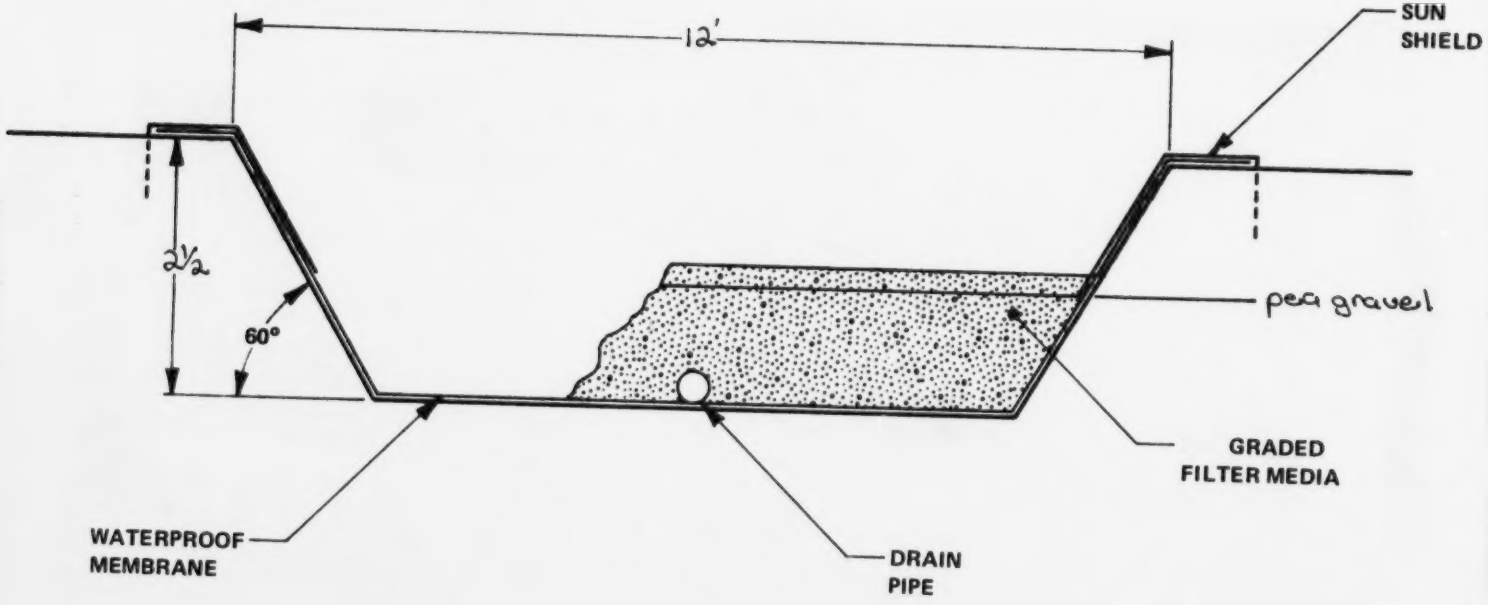

Figure 3. Elevation view of elimination trench.

SAMPLING AND ANALYTICAL METHODOLOGY

Automatic composite samplers were used with sample intervals at 15 minutes for the 24-hour composite samples collected from Sunday through Thursday of each week for the chemical analyses. Daily grab samples were used for measurement of physical parameters. All laboratory results were recorded on daily sheets and then transferred to montly sheets for each sampling location. Monthly averages were calculated and recorded.

All analyses were performed according to Standard Methods for the Examination of Water and Wastewater (14th Edition, 1976. American Public Health Association, Washington, D.C.) as shown below:

Analysis	Standard Methods Procedure Number
Total suspended solids (TSS)	208E
Volatile suspended solids (VSS)	208G
Biological oxygen demand (BOD_5)	507
Chemical oxygen demand (COD)	508
Ammonium nitrogen (NH_4-N)	413J
Kjeldahl nitrogen (TKN)	413J
Organic nitrogen (TKN)	413J
Nitrite Nitrogen (NO_2-N)	420
Nitrate nitrogen (NO_3-N)	419D
Total phosphorus (TP)	425F
pH (pH)	424

SECTION 5

OPERATIONAL EXPERIENCES WITH THE MPI SYSTEM

TEST OF MPI SYSTEM AS A TERTIARY TREATMENT PROCESS

Secondary effluent from the MNWD extended aeration plant was introducted to the MPI system on July 1, 1978, at a loading rate of 56 m^3/d (15,000 gpd) and the flow was increased to 95 m^3/d (25,000 gpd) in August.

The newly planted Pragmites planted in both the filter and elimination trenches grew very slowly. It was not clear whether this slow growth was due to a lack of sufficient nutrients in the influent, not providing a wet enough environment in the trench after initial planting, or whether the plants were extending their subsurface root systems rather than extending their above-ground growth. In mid-July, the operational procedure was changed so that the filter trench being used on a particular day was allowed to fill before the discharge valve was opened. This change seemed to improve the growth rate of the plants. Some of the Pragmites planted died and these areas had to be re-planted. The Scirpus in the elimination trench did not experience growth problems and attained a height of 1.6-2.0 m (5-6 ft) by September. BWP of New York has found that Phragmites is quite delicate during the first 3-4 months of growth. They feel that a very wet environment should be provided for about 4 weeks after planting.

Growth of algae within the clear plastic tubes for the composite samplers and on the weirs in the middle of the elimination trenches recurred and could possibly effect the results of chemical analyses. Black plastic tubes which prevented light from reaching the tubing solved the problem with the sampler. A large sheet of plywood was placed over the area of the weirs and splash zone to cut down the sunlight and algal growth in that area.

In the first months of operation and testing, a major problem was due to rodents in the area grazing on the young shoots of the growing plants. This occurred at a time when the vegetation on the surrounding hills was drying during the hot summer months. Within a short time, ten to twenty rabbits and squirrels invaded the trench every evening. Trapping, and later rodent repellents were used to limit the rodent activity. As the plants reached a more mature height, the problem eased but rodents returned briefly after each harvest.

TEST OF MPI SYSTEM AS A SECONDARY TREATMENT PROCESS

Screened raw wastewater was used as the influent to the MPI system in mid-September at a rate of 56 m^3/d (15,000 gpd). The flow was increased to

95 m^3/d (25,000 gpd) in October and to a rate of 133 m^3/d (35,000 gpd) in January. It remained at this rate through July.

A thin sludge layer built up and completely covered the filter trenches by the end of October. At this time, the Phragmites had not spread throughout the trenches. Algae also started to grow on the sludge layer, and it is possible that this algae may have contributed to later clogging problems. By mid-December, algae covered a large portion of the sludge layer and the sludge layer was not drying or breaking up while the flow was directed into the alternate trench. The problem occurred equally in both filter trenches. Operation was suspended at this time to consider this problem and to harvest the Phragmites from the filter trenches. The Phragmites had turned brown because of unusually cold weather and began to lay over because of their mature height and weight. When the sludge layer was skimmed off a little at a time, it was found that about 25 mm (1 in) of sludge was deposited on the filter media; this sludge layer was wet and becoming septic. Below this was a layer of compacted organic matter and fibers that were black in appearance and felt greasy; this intermingled with the sand, formed an almost impermeable layer. If a hole was piked through this layer, the liquid held in the sludge layer immediately drained through the remaining sand. The only solution at this time was to allow the filter trenches to dry after the harvesting, then carefully rake out the semi- dry top sludge layer.

In mid-November, another change was attempted to prevent the trenches from clogging. The pipes which drain the filter trenches run along the bottom of each filter trench and then into the sump. At this point of emergence into the sump, there is a tee fitting and the stem of the tee is pointing upward and open to allow the insertion of a sampling probe. Originally, the tee end was capped, but this was found to slow the rate of draining of the filter trenches and cause clogging of the sampler probe. The removal of the cap did help draining to be more efficient, but this still did not have any effect on the status of the continuous sludge buildup and clogging of the trenches' top layer. Also at this time, the pump which directed the raw wastewater to the filter trenches developed a serious leak and a new pump had to be installed.

Subsequent tests conducted in Long Island, N.Y., by BWP of New York, Inc. showed that the use of four parallel filter trenches to allow increased drying time and draining the filter trenches three times a week minimized this sludge problem.

After one month of operation with the screened raw wastewater, the unplanted gravel of the splash zone at the beginning of the elimination trench area began to clog and a temporary ponding occurred. The gravel was replaced with new gravel but clogging began again three weeks later. Phragmites were planted in these areas to see whether their root systems would keep the gravel unclogged; only temporary success was achieved. It was learned that the load of deposited solids which flowed to the elimination trenches could be handled better when the filter trench sump was flushed out daily rather than weekly.

Originally, the flow to the elimination trenches was continuous and split between the two elimination trenches. During the third month of operation, the flow to the elimination trenches was alternated in a manner similar to the flow to the filter trenches. The purpose of this was to determine whether a single elimination trench could be loaded to a rate of 95 m^3/d (25,000 gpd) and whether there was any effect caused by the low or reduced flow to the elimination trench being rested on that day. Although the drained trench appeared to become septic, it could not be determined whether this was caused by the alternate operation or by the fact that retention time was halved at this flow rate. At the beginning of December, each elimination trench was switched back to a continuous flow of 47 m^3/d (12,500 gpd. Even with continuous flow, it was found that the elimination trenches should be drained alternately every two days to minimize the onset of anaerobic conditions.

As was mentioned before, the project was shut down through the latter part of December and early January because of the sludge problems, overflow caused by very heavy rains, pump malfunctions, and the cutoff of raw influent due to a mechanical problem with the extended aeration activated sludge plant.

When start-up occurred in mid-January, the flow to the trenches was increased to 133 m^3/d (35,000 gpd). Even though the filter trenches had been harvested at the end of December and the thick sludge buildup had been removed, another heavy sludge layer appeared quickly. This level of feed, 133 m^3/d (35,000 gpd), apparently was more than the filter trenches could handle. Heavy rains at this time caused further problems. When first built, the filter trenches had nearly 150 mm (6 in) of freeboard from the gravel bed to the top, but with the heavy rains and also because of repairs of pipes within the trench, the sides settled to a level of only 50 to 75 mm (2 to 3 in) of freeboard in some areas. This prevented an even flow distribution over the trenches, reduced the surface holding capacity, and reduced the head available for forcing the liquid through the filter. Because of the continuous rainy days, the trenches were unable to dry completely and this may also have contributed to the problem of clogging and overflow.

In February, the trenches were operated 24 of the 28 days; surface runoff into the trenches caused by heavy rains forced a shutdown the other four days. Application was changed to two days per trench, instead of alternating daily, to see if this flow pattern would aid in drying the surface of the idle trench. No observable improvement occurred; alternating daily between the filter trenches was resumed. The influent flow during the latter part of the month occasionally dropped to 57-75 m^3/d (15,000-20,000 gpd) because of a clogged influent valve. After this the valve was cleaned out once a week to prevent this from occurring. The splash zone at the inlet of the elimination trenches again began to pond. Once more the gravel was replaced at this point.

In March the MPI system was only on line 6 out of 31 days because of surface runoff. Influent flow was reduced to 95 m^3/d (25,000 gpd) but ponding and uneven filtering still occurred in the filter trenches. The walkway between the filter trenches subsided to such an extent that there was no longer any freeboard. The construction company that had built the trenches was contacted for repair work but could not do the repairs until May. Nearly 150 mm (6 in) of rain fell in March, the wettest month of the study. The wind

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
EPA Form 2350-6 (4-80)
(PREVIOUSLY CIN. EPA FORM 2.6)
PAGE NUMBER
U.S. GOVERNMENT PRINTING OFFICE: 1980-820-630
TYPING GUIDE SHEET

and rain flattened the bulrushes growing in the elimination trenches. The plants were harvested at the end of the month.

In April the rain decreased and a flow of 133 m^3/d (35,000 gpd) through the MPI system was again attempted. The system was only operated for about one half of the month because of the surface runoff problem and a blockage that occurred in the main influent line to the 3A facility. The obstruction was found and removed after shutting down the system for over one week. Once more the gravel was replaced under the elimination trench splash zone because of clogging. After replacing the gravel in this area this time, that particular zone was hosed down daily with a high pressure hose to help prevent clogging.

Since the previous harvest in January, the reeds had grown 2 meters (6 ft 6 in). The fastest growing periods corresponded to the months with the greatest amount of rain and to the periods after harvesting. At the end of April, the reeds were again harvested and the heavy sludge layer removed. Harvesting, including cleanup and removal of plants and the sludge layer required approximately five working days for the filter trenches and three working days for the elimination trenches.

The sides of the filter trenches were finally repaired during the middle of May by placing sand under the sides and walkway of the trench. With the end of the rainy season and the sides rebuilt, the surface runoff problem ceased.

The sampling location of the elimination trench influent was also changed in May. Instead of alternating the sample line placement in the standpipes daily, corresponding to the particular filter trench in use, the sample line was placed directly into the sump. Thus, the sample would reflect the underdrain quality during all conditions, including draining.

Problems continued to occur in June. An attempt was made to minimize the clogging at the splash zone of the elimination trenches by moving back the berms about 3 meters (9 ft), allowing more area. This helped for a while, but did not completely prevent clogging caused by algal growth between and on top of the gravel layers. During the first three weeks of June, the weather was overcast and damp which made drying of the filter trench more difficult. With the advent of warmer weather, insect larvae were in abundance in the sumps and in the samples taken.

By the end of June, the reeds in the filter trenches had grown to a height of 1.5 meters (5 ft). The rate of growth appeared to slow down slightly with the dryer weather and maturing of the plants. In reviewing the growth pattern and density of the reeds, one could see areas of the trenches with no reeds up through the second harvest in December. However, during the rainy season, growth was prolific and the plants densely filled both trenches by the third harvest. In the elimination trenches, the bulrush and reeds were harvested as frequently as in the filter trenches. The bulrush grew very well through the entire project; the only problems with the bulrush were that because of their weight, they would not stand up in heavy rain and wind. It may be necessary to harvest more frequently during these periods. Also in

June, when higher temperatures were present, the top half of the plants became brown.

The project was terminated in July 1979 because of the sudden death of Mr. James O'Connor, the project manager.

SECTION 6

RESULTS AND DISCUSSION

MPI SYSTEM OPERATED AS A TERTIARY TREATMENT PROCESS

The results of the analytical program for samples obtained during the time extended aeration effluent was applied to the system, are shown in Table 1, for the months of July and August 1978.

Overall removal of BOD_5, VSS, and TSS was about 50 percent each month. COD reduction was about 40 percent. Ammonium nitrogen removal of 67 percent during August was superior to the 40 percent removal in July. Consideration of the NH_4-N, NO_3-N and NO_2-N valves between the two months indicates nitrification and subsequent denitrification were more active in the system during the warmer month of August. TKN samples were not collected during this period.

TP removal was not efficiently achieved by the MPI system operated as a tertiary process.

The extended aeration effluent applied to the system was of good quality. The filter trench achieved the greater part of the overall pollutant removals, with the elimination trench showing only marginal incremental removal.

MPI SYSTEM OPERATED AS A SECONDARY TREATMENT PROCESS

The operation of the MPI system for treatment of raw, screened wastewater was started on September 8, 1978. For evaluation, both filter trench results were averaged together, as were both elimination trenches since preliminary results showed efficiencies of the Phragmites and Scirpus in the elimination trench were similar.

The major objective of this project was to evaluate the MPI system as a low cost wastewater treatment alternative which would satisfy Federal discharge requirements. These requirements are attainment of final effluent BOD_5 and SS concentrations not to exceed 30 mg/l for 30 days average values, or 85 percent overall removal, whichever is more stringent.

The system was evaluated for secondary treatment effectiveness for 11 months as shown in Table 2. For five of the months, the flow through the system was 95 m^3/d (25,000 gpd) or less. For six of the months, the flow through the system was 133 m^3/d (35,000 gpd). Secondary treatment requirements for BOD_5 and SS were achieved all five months at the lower flow. At the higher flow rate, SS residuals and percent removals met secondary requirements all six months; however, the BOD_5 requirement was not achieved for five of

Table 1. Tertiary Treatment Results for MPI System
(Monthly Average Values)

Item, mg/l	MNWD Secondary Effluent	Filter Trench Effluent	Elimination Trench Effluent	Overall Removal, %
July 1978, flow 25,000 gpd				
BOD_5	16	11	7	56
TSS	18	10	8	56
VSS	11	6	4	64
COD	65	54	41	37
NH_4-N	15	11	9	40
NO_2-N	0.9	3.2	2.0	-
NO_3-N	1.3	5.5	8.6	-
TP	9.8	9.0	9.1	7
pH, Units	7.6	7.5	7.5	-
August, 1978, flow 25,000 gpd				
BOD_5	13	7	6	54
TSS	12	6	6	50
VSS	9	5	4	56
COD	50	46	30	40
NH_4-N	9	5	3	67
NO_2-N	0.7	0.7	0.2	-
NO_3-N	2.9	5.0	5.7	-
TP	13.2	11.1	10.8	18
pH, Units	7.2	7.1	7.2	-

the six month. Three times the effluent violated both the concentration and percent removal requirements (January, April, and July). The percent removal requirement was violated twice (May and June).

There was little difference in overall COD removal for the two application rates. For flows of 95 m^3/d or less, the average was 78 percent and for the higher flow, the average was 76 percent with only slight variation between months.

The NH_4-N and Org-N concentration values in the effluent during the periods of 95 m^3/d application were representative of conventional secondary treatment residuals. Variations in percent removals are due to fluctuations in influent concentrations. The overall removal of total nitrogen varied from 61 percent in September to 32 percent in March.

During application of 133 m^3/d the organic nitrogen residuals were about twice the values of the lower flow rate results. During February a negative removal of Org-N was noted. The overall removal of total nitrogen was much lower than during the 95 m^3/d application. Values ranged from 18 percent in January to 36 percent in June.

Nitrite and nitrate nitrogen concentrations for all the sample periods show that nitrification did not occur to any significant extent at either of the two flow rates.

The MPI system during both the 95 m^3/d and the 133 m^3/d application rates was not effective for total phosphorus removal. During the higher application rate, two months (January and June) showed negative removals.

All sample periods showed a reduction in the pH value of about 1 unit between the influent and elimination trench effluent, with the major fraction of the decrease occurring in the filter trench.

Total coliform tests were performed once every two weeks during the months of December 1978 through March 1979 using the Most Probable Number (MPN) method with final effluent dilution of 0.1, 0.01 and 0.001 ml. All test results showed effluent total coliforms to be greater than 240,000 per 100 ml.

Table 2 shows that the major increment of BOD_5, SS, VSS, and COD removal occurs at the filter trench and the elimination trench serves as a polishing process. Both trenches in series are necessary for satisfactory treatment.

The MPI system operated with raw screened wastewater at an application rate of 95 m^3/d did achieve secondary effluent quality. Using the trench measurements given in Section 4, it can be calculated that the spatial requirements of the MPI system equate to 0.02 $m^3/m \cdot d$ (0.5 gpd/ft^2). Assuming a per capita wastewater discharge of 378 l (100 gal), the area required is 2 m^2/capita (21 ft^2/capita). These two values are very similar to spatial requirements of a septic tank system located in a satisfactory percolating soil.

Table 2. Secondary Treatment Results for MPI System.
(Monthly Average Values)

Sample Location	BOD_5	TSS	VSS	COD	NH_4-N	Org-N	NO_2-N	NO_3-N	TP	pH, Units
September, 1978 mg/l flow 15,000 gpd										
Influent Wastewater	203	205	176	501	21	15	0.0	0.1	13.0	7.2
Filter Trench Effluent	68	42	32	246	15	6	0.2	0.9	12.6	7.1
Elimination Trench Effluent	26	19	14	102	10	4	0.1	0.4	11.0	7.0
Overall Removal, Percent	87	91	92	80	52	73	-	-	15	-
October, 1978 mg/l flow 25,000 gpd										
Influent Wastewater	210	196	168	448	24	12	0.0	0.1	10.6	7.5
Filter Trench Effluent	66	42	36	142	16	8	0.8	1.0	12.6	7.0
Elimination Trench Effluent	23	19	15	86	13	4	0.1	0.6	9.9	6.9
Overall Removal, Percent	89	90	91	81	46	67	-	-	7	-
November, 1978 mg/l flow 25,000 gpd										
Influent Wastewater	212	250	220	366	23	13	0.0	0.1	12.8	7.5
Filter Trench Effluent	86	46	40	150	19	7	0.3	1.0	14.0	6.8
Elimination Trench Effluent	27	24	20	93	16	6	0.1	0.4	12.9	6.8
Overall Removal, Percent	87	90	91	75	30	54	-	-	3	-

Table 2. (Cont'd) Secondary Treatment Results for MPI System.
(Monthly Average Values)

Sample Location	BOD_5	TSS	VSS	COD	NH_4-N	Org-N	NO_2-N	NO_3-N	TP	pH, Units
December, 1978 mg/l flow 25,000 gpd										
Influent Wastewater	228	264	230	360	24	11	0.0	0.1	13.2	7.5
Filter Trench Effluent	78	46	38	183	21	19	0.3	1.0	12.3	6.4
Elimination Trench Effluent	26	20	16	80	18	3	0.1	0.4	12.0	6.7
Overall Removal, Percent	86	92	93	78	25	73	-	-	9	-
January, 1979 mg/l flow 35,000 gpd										
Influent Wastewater	214	146	144	375	23	27	0.0	0.2	11.3	7.9
Filter Trench Effluent	85	47	40	161	22	32	0.3	1.4	12.7	6.8
Elimination Trench Effluent	38	21	18	77	17	16	0.0	0.7	12.9	6.8
Overall Removal, Percent	82	86	88	79	26	41	-	-	(-14)	-
February, 1979 mg/l flow 35,000 gpd										
Influent Wastewater	190	189	162	381	26	11	0.0	0.3	11.7	7.7
Filter Trench Effluent	79	45	37	156	18	9	0.7	1.6	11.7	6.6
Elimination Trench Effluent	24	17	15	83	15	14	0.1	0.7	11.7	6.6
Overall Removal, Percent	87	91	91	78	42	(-27)	-	-	0	-

Table 2. (Cont'd) Secondary Treatment Results for MPI System.
(Monthly Average Values)

Sample Location	BOD_5	TSS	VSS	COD	NH_4-N	Org-N	NO_2-N	NO_3-N	TP	pH, Units
March, 1979 mg/l flow 25,000 gpd										
Influent Wastewater	198	210	182	380	29	12	0.0	0.1	13.4	7.8
Filter Trench Effluent	88	62	52	174	25	7	0.4	0.5	12.1	6.7
Elimination Trench Effluent	30	18	16	82	22	6	0.1	0.2	12.1	6.7
Overall Removal, Percent	85	91	91	78	24	50	-	-	10	-
April, 1979 mg/l flow 35,000 gpd										
Influent Wastewater	166	186	162	386	29	9	0.0	0.2	17.7	7.7
Filter Trench Effluent	58	48	42	177	26	8	0.8	1.9	15.7	6.6
Elimination Trench Effluent	31	19	16	91	25	7	0.1	0.2	15.8	6.8
Overall Removal, Percent	81	90	90	76	14	22	-	-	11	-
May, 1979 mg/l flow 35,000 gpd										
Influent Wastewater	159	138	118	444	24	28	0.2	0.6	13.8	7.7
Filter Trench Effluent	56	38	34	165	21	6	0.8	1.4	13.0	6.8
Elimination Trench Effluent	25	20	15	98	21	12	0.3	1.4	11.6	6.8
Overall Removal, Percent	84	86	87	78	13	57	-	-	16	-

Table 2. (Cont'd) Secondary Treatment Results for MPI System.
(Monthly Average Values)

Sample Location	BOD_5	TSS	VSS	COD	NH_4-N	Org-N	NO_2-N	NO_3-N	TP	pH, Units
June, 1979 mg/l flow 35,000 gpd										
Influent Wastewater	155	188	162	419	22	10	0.0	0.1	12.1	7.4
Filter Trench Effluent	64	40	36	164	18	14	0.4	0.3	12.1	6.6
Elimination Trench Effluent	27	16	14	98	19	6	0.1	0.2	13.5	6.8
Overall Removal, Percent	83	91	91	77	14	40	-	-	(-12)	-
July, 1979 mg/l flow 35,000 gpd										
Influent Wastewater	143	240	204	422	-	-	0.1	0.2	11.6	7.4
Filter Trench Effluent	68	40	32	118	-	-	0.6	0.4	11.9	6.5
Elimination Trench Effluent	31	20	18	112	-	-	0.2	0.1	11.4	6.6
Overall Removal, Percent	78	92	91	73	-	-	-	-	2	-

Section 5 detailed the several operating problems that occurred during this demonstration study. These occurrences are to be expected with new technology development. This initial assessment of the efficiency and spatial considerations for the MPI system for secondary treatment indicates it is worthy of further development. Many of the same operational problems were encountered at the Long Island, New York, installation. Remedial measures applied there included provision for increased area for the filter trenches, thereby allowing longer idle times for drying. Also the Long island study showed that frequent harvesting of the plants used in the system promotes extra growth of the root systems and this contributes to clogging. Their recommendation is to harvest plants not more than once a year. If plant growth becomes excessive during the year, individual plants are culled by pulling to thin the growth.